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O'Neil et al.

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(54) **FLEXIBLE DISPLAY HINGED DEVICE**

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(73) Assignee: **Microsoft Technology Licensing, LLC**, Redmond, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/853,536**

(22) Filed: **Dec. 22, 2017**

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(51) **Int. Cl.**

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H04M 1/02	(2006.01)
E05D 7/00	(2006.01)
E05D 1/04	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 1/1616*** (2013.01); ***E05D 1/04*** (2013.01); ***E05D 7/00*** (2013.01); ***G06F 1/1641*** (2013.01); ***G06F 1/1652*** (2013.01); ***G06F 1/1681*** (2013.01); ***H04M 1/0216*** (2013.01); ***H04M 1/0268*** (2013.01); *E05Y 2900/606* (2013.01); *G06F 2203/04102* (2013.01)

(58) **Field of Classification Search**

CPC H05K 5/00

See application file for complete search history.

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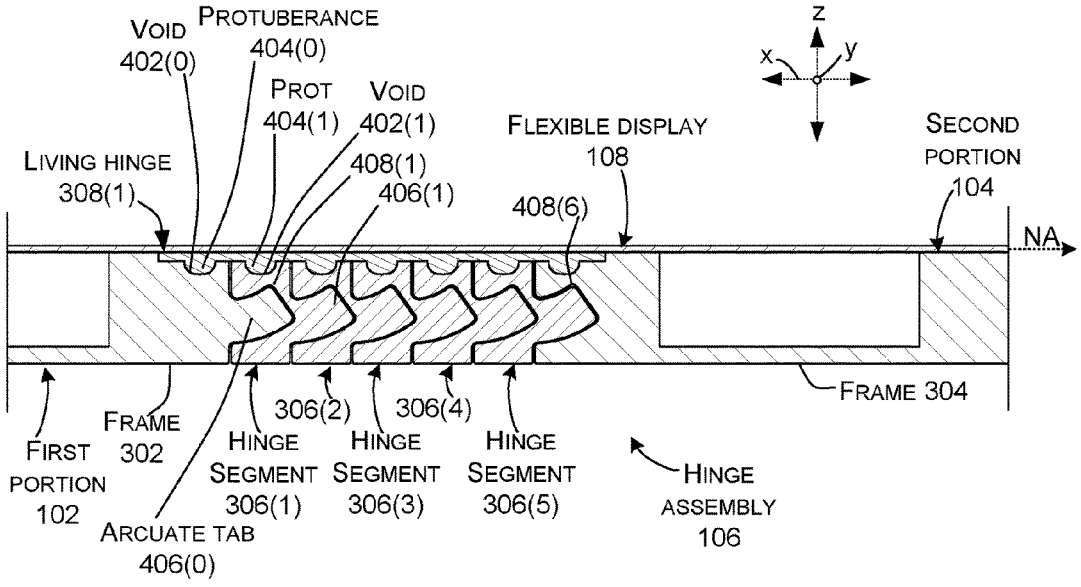
Primary Examiner — Jerry Wu

(74) *Attorney, Agent, or Firm* — Rainier Patents, P.S.

(57) **ABSTRACT**

The description relates to devices, such as computing devices that have hinged portions. One example can include a first portion and a second portion. The example can also include a first exoskeletal hinge segment secured to the first portion and a second exoskeletal hinge segment secured to the second portion. The first exoskeletal hinge segment can define an arcuate tab that travels in an arcuate cavity defined by the second exoskeletal hinge segment to allow relative rotation between the first and second portions.

20 Claims, 16 Drawing Sheets



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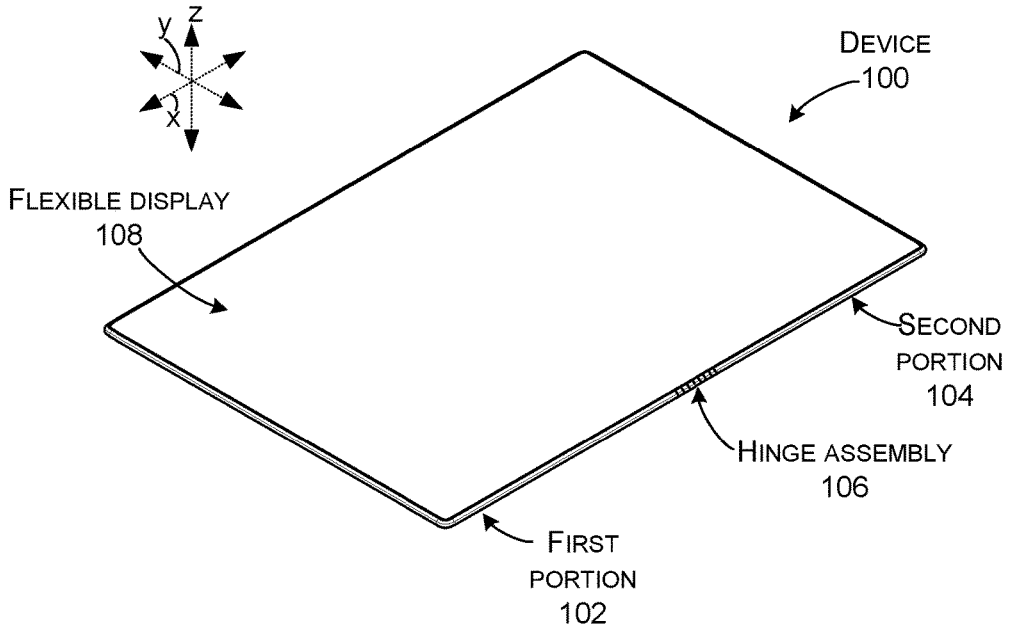


FIG. 1A

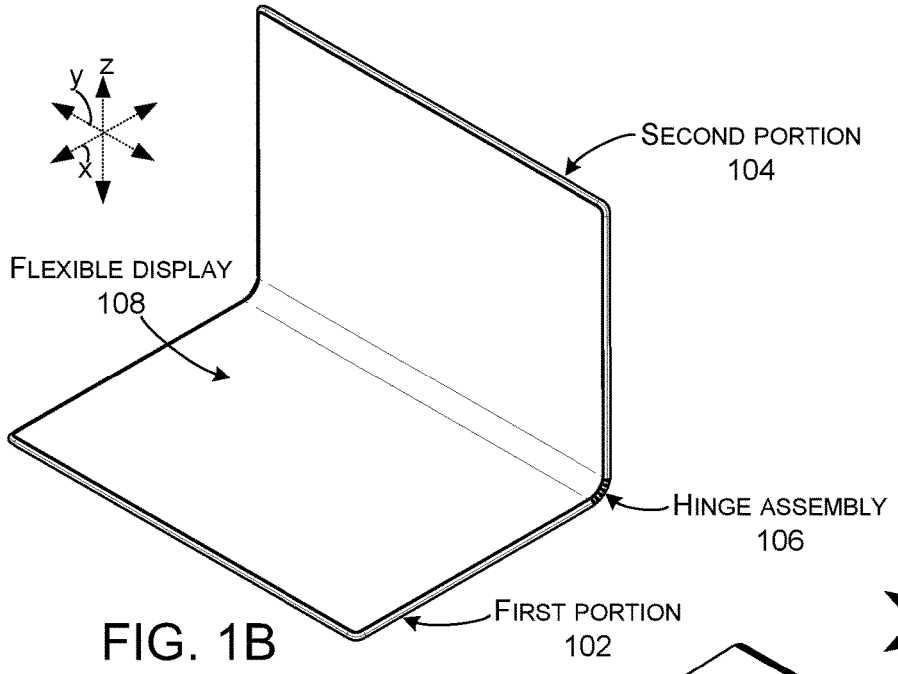


FIG. 1B

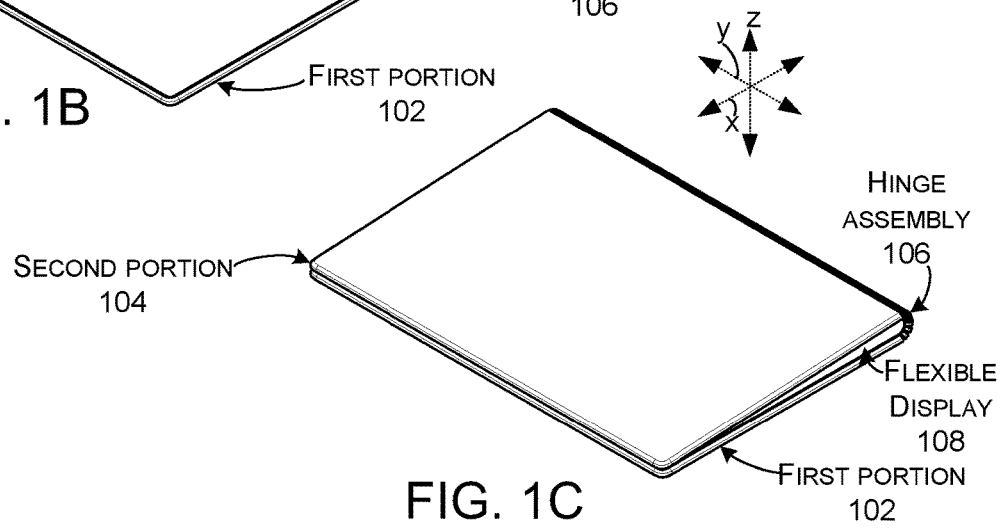


FIG. 1C

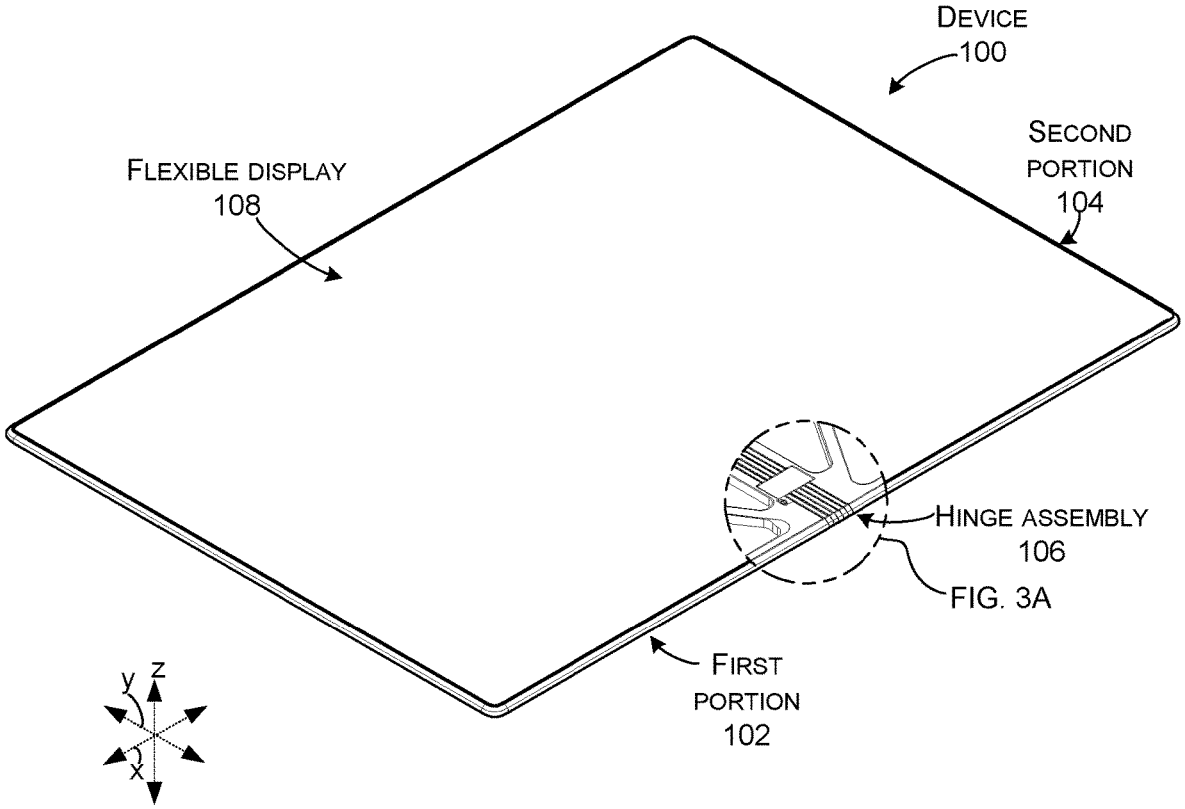

DEVICE
100
SECOND
PORTION
104
FLEXIBLE DISPLAY
108
HINGE ASSEMBLY
106
FIG. 3A
FIRST
PORTION
102
y
z
x

FIG. 2

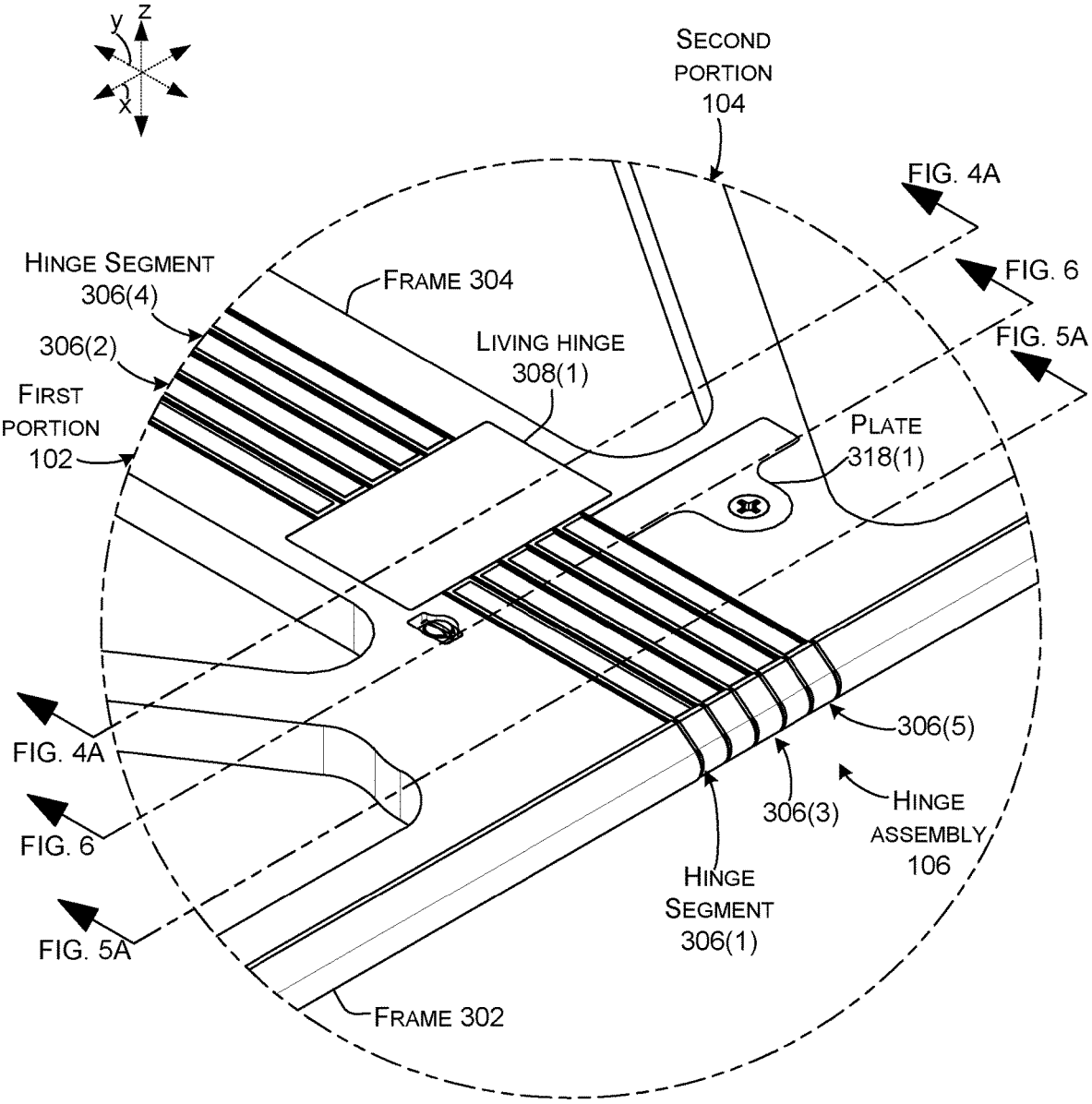

y
z
x
SECOND PORTION 104
FIG. 4A
FIG. 6
FIG. 5A
HINGE SEGMENT 306(4)
306(2)
FIRST PORTION 102
FRAME 304
LIVING HINGE 308(1)
PLATE 318(1)
FIG. 4A
FIG. 6
FIG. 5A
306(5)
306(3)
HINGE ASSEMBLY 106
HINGE SEGMENT 306(1)
FRAME 302

FIG. 3A

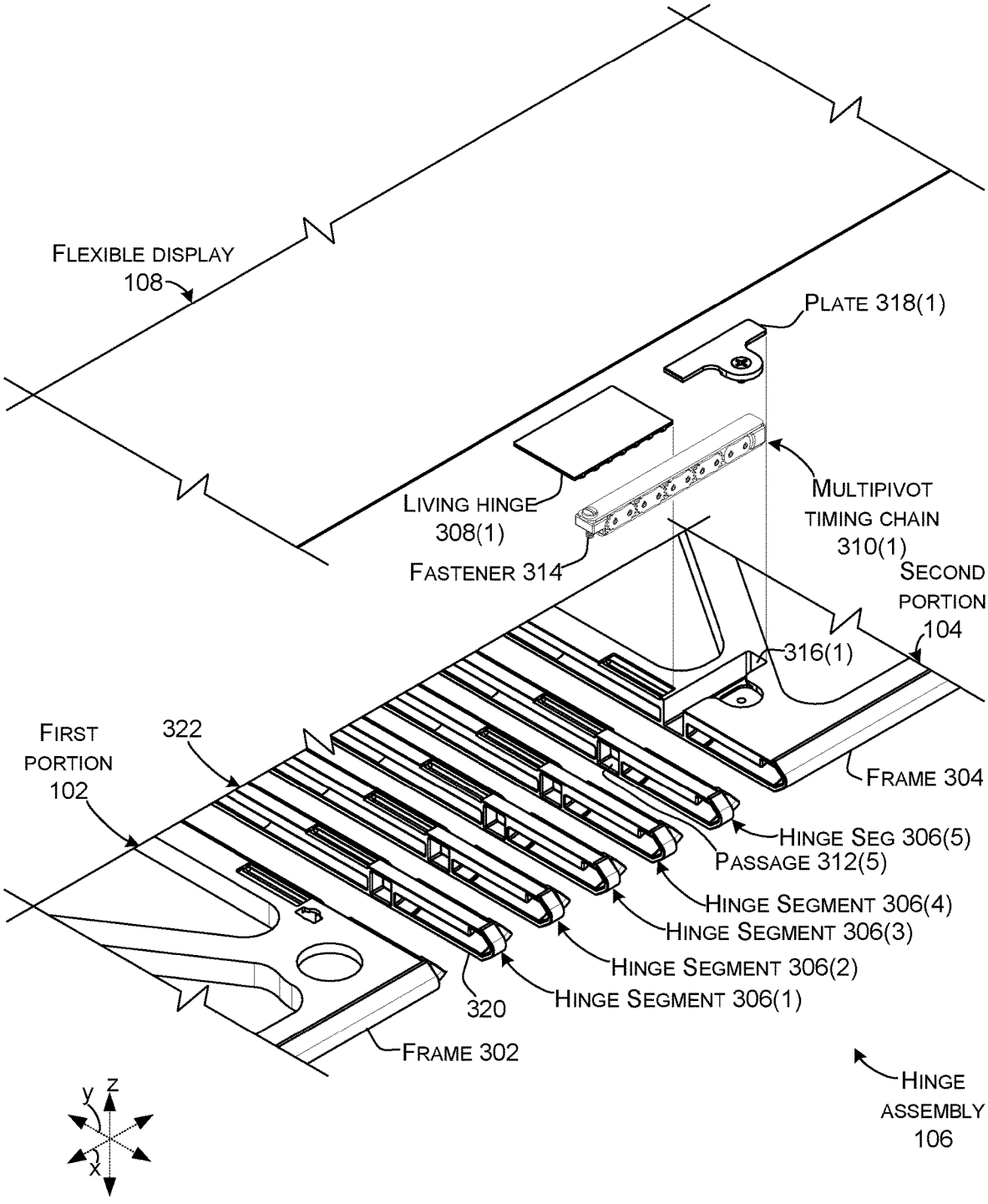

FLEXIBLE DISPLAY
108
PLATE 318(1)
LIVING HINGE
308(1)
MULTIPIVOT
TIMING CHAIN
310(1)
FASTENER 314
SECOND
PORTION
104
316(1)
FIRST
PORTION
102
322
FRAME 304
HINGE SEG 306(5)
PASSAGE 312(5)
HINGE SEGMENT 306(4)
HINGE SEGMENT 306(3)
HINGE SEGMENT 306(2)
HINGE SEGMENT 306(1)
320
FRAME 302
HINGE
ASSEMBLY
106
y
z
x

FIG. 3B

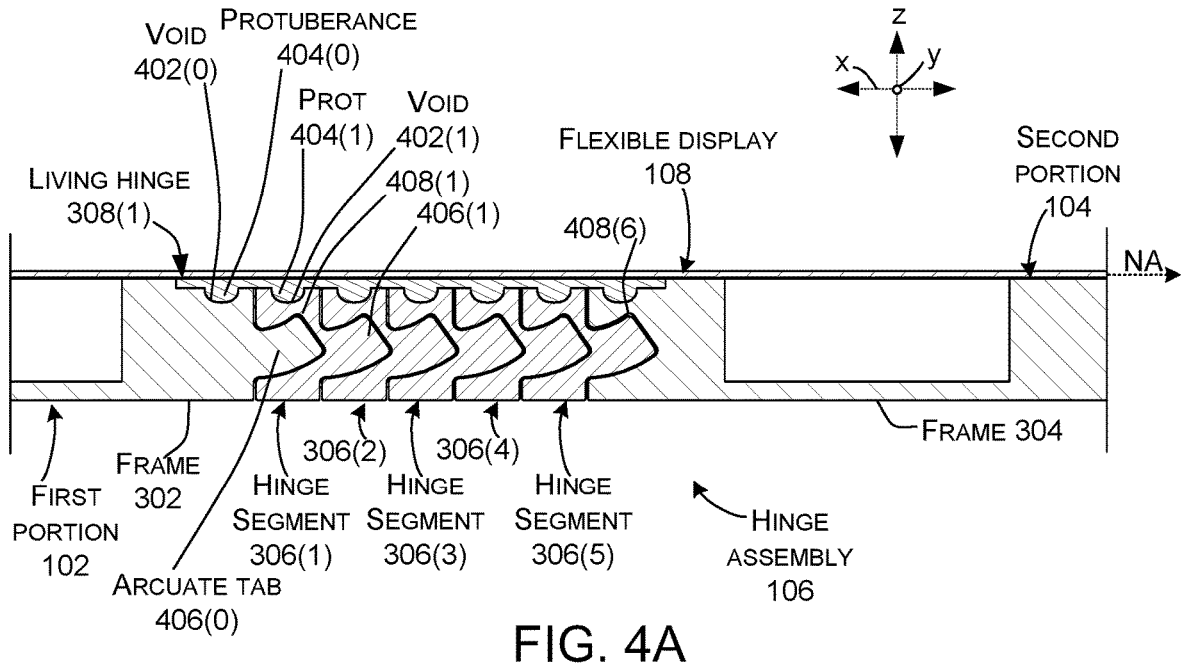

VOID 402(0)
PROTUBERANCE 404(0)
PROT 404(1)
VOID 402(1)
408(1)
406(1)
LIVING HINGE 308(1)
FLEXIBLE DISPLAY 108
408(6)
SECOND PORTION 104
NA
z
x
y
FRAME 304
FIRST PORTION 102
FRAME 302
ARCUATE TAB 406(0)
HINGE SEGMENT 306(1)
306(2)
HINGE SEGMENT 306(3)
306(4)
HINGE SEGMENT 306(5)
HINGE ASSEMBLY 106

FIG. 4A

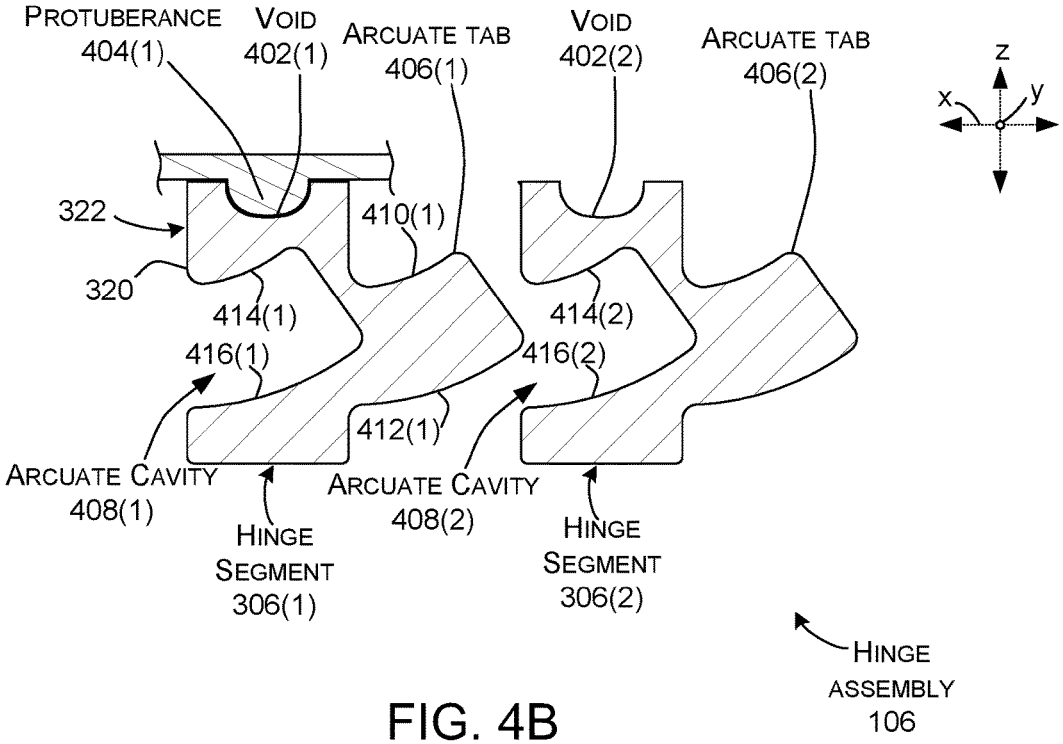

PROTUBERANCE 404(1)
VOID 402(1)
ARCUATE TAB 406(1)
VOID 402(2)
ARCUATE TAB 406(2)
z
x
y
322
410(1)
320
414(1)
416(1)
414(2)
416(2)
412(1)
ARCUATE CAVITY 408(1)
HINGE SEGMENT 306(1)
ARCUATE CAVITY 408(2)
HINGE SEGMENT 306(2)
HINGE ASSEMBLY 106

FIG. 4B

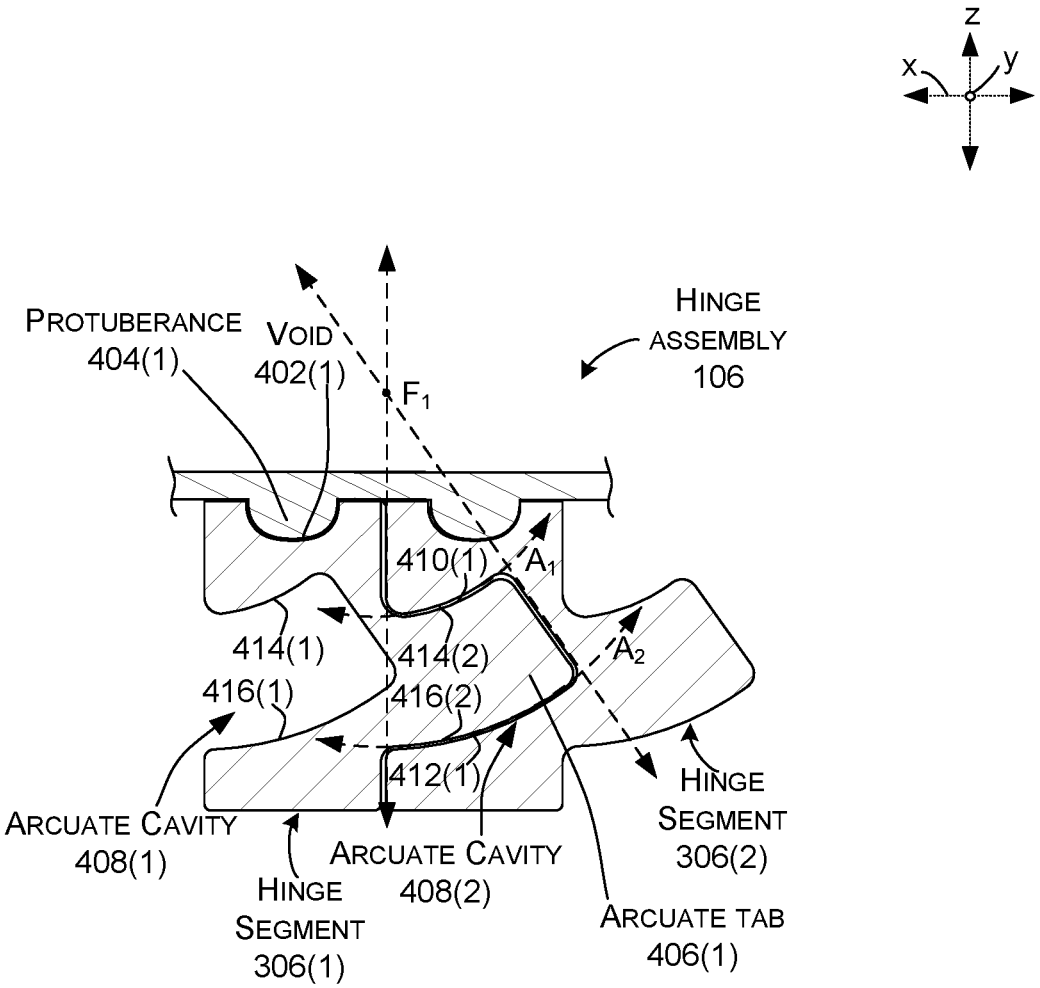

z
x
y
PROTUBERANCE
404(1)
VOID
402(1)
F_1
HINGE
ASSEMBLY
106
410(1)
A_1
414(1)
416(1)
414(2)
416(2)
A_2
412(1)
ARCUATE CAVITY
408(1)
HINGE
SEGMENT
306(1)
ARCUATE CAVITY
408(2)
HINGE
SEGMENT
306(2)
ARCUATE TAB
406(1)

FIG. 4C

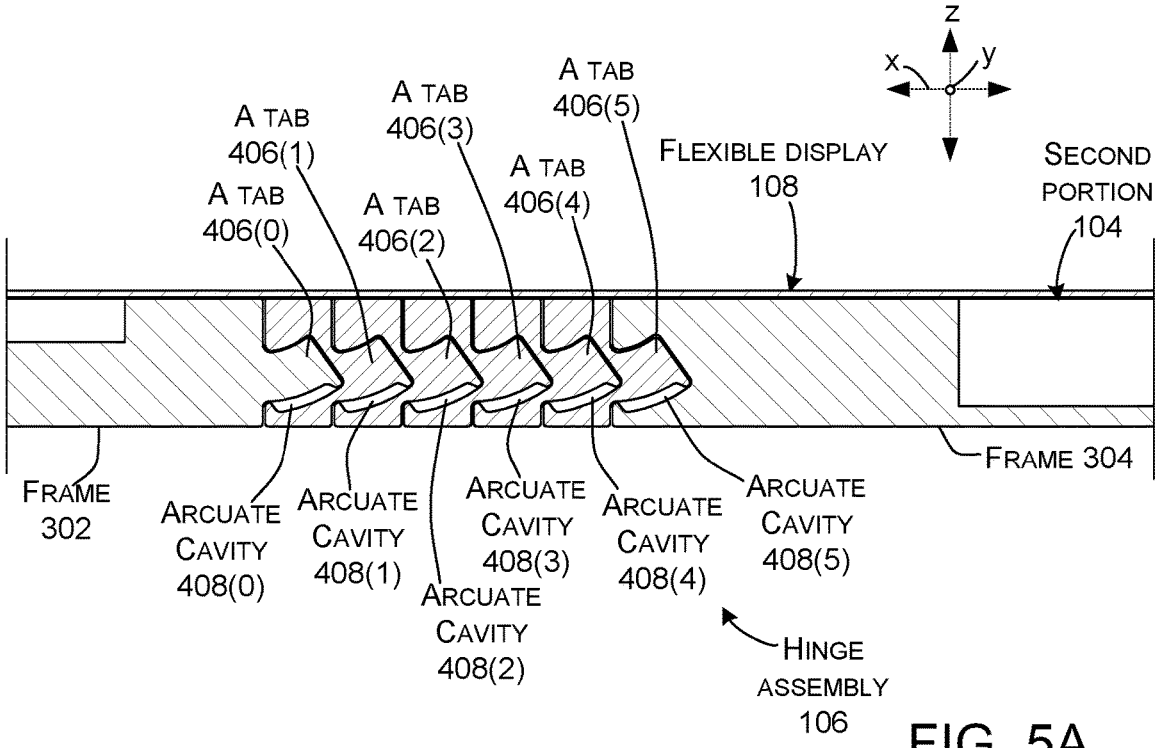


FIG. 5A

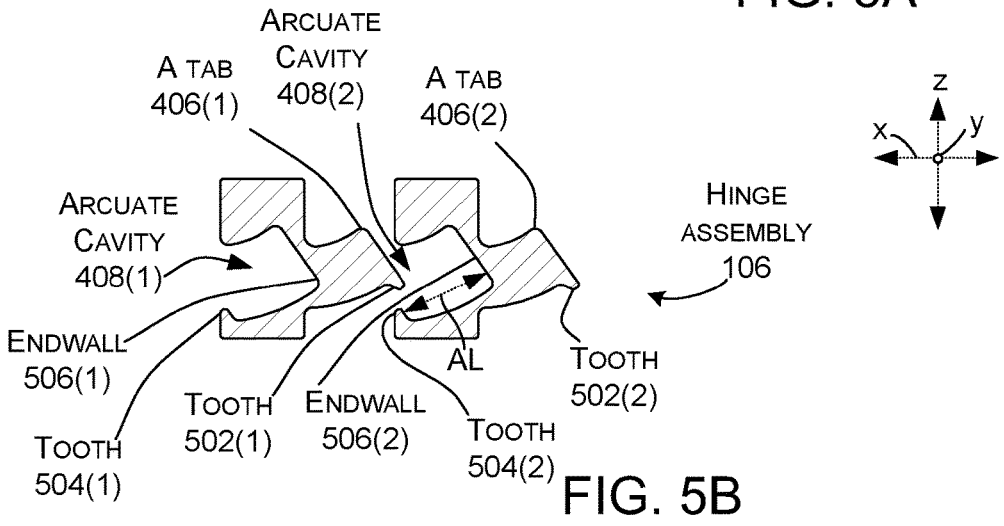


FIG. 5B

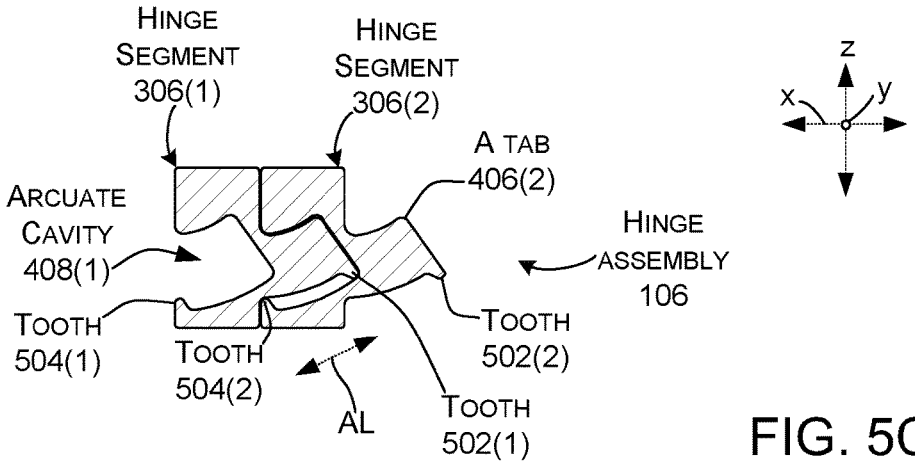
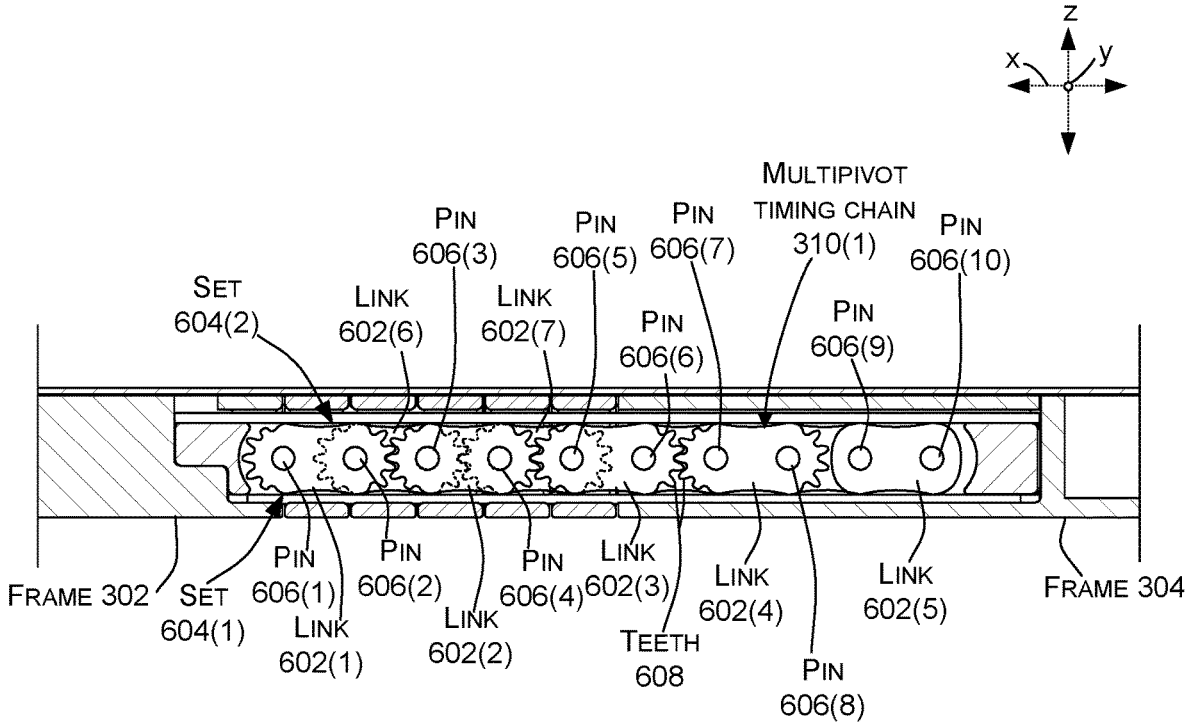


FIG. 5C


z
x
y
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PIN 606(3)
PIN 606(5)
PIN 606(7)
PIN 606(10)
SET 604(2)
LINK 602(6)
LINK 602(7)
PIN 606(6)
PIN 606(9)
FRAME 302
SET 604(1)
PIN 606(1)
LINK 602(1)
PIN 606(2)
LINK 602(2)
PIN 606(4)
LINK 602(3)
TEETH 608
LINK 602(4)
PIN 606(8)
LINK 602(5)
FRAME 304

FIG. 6

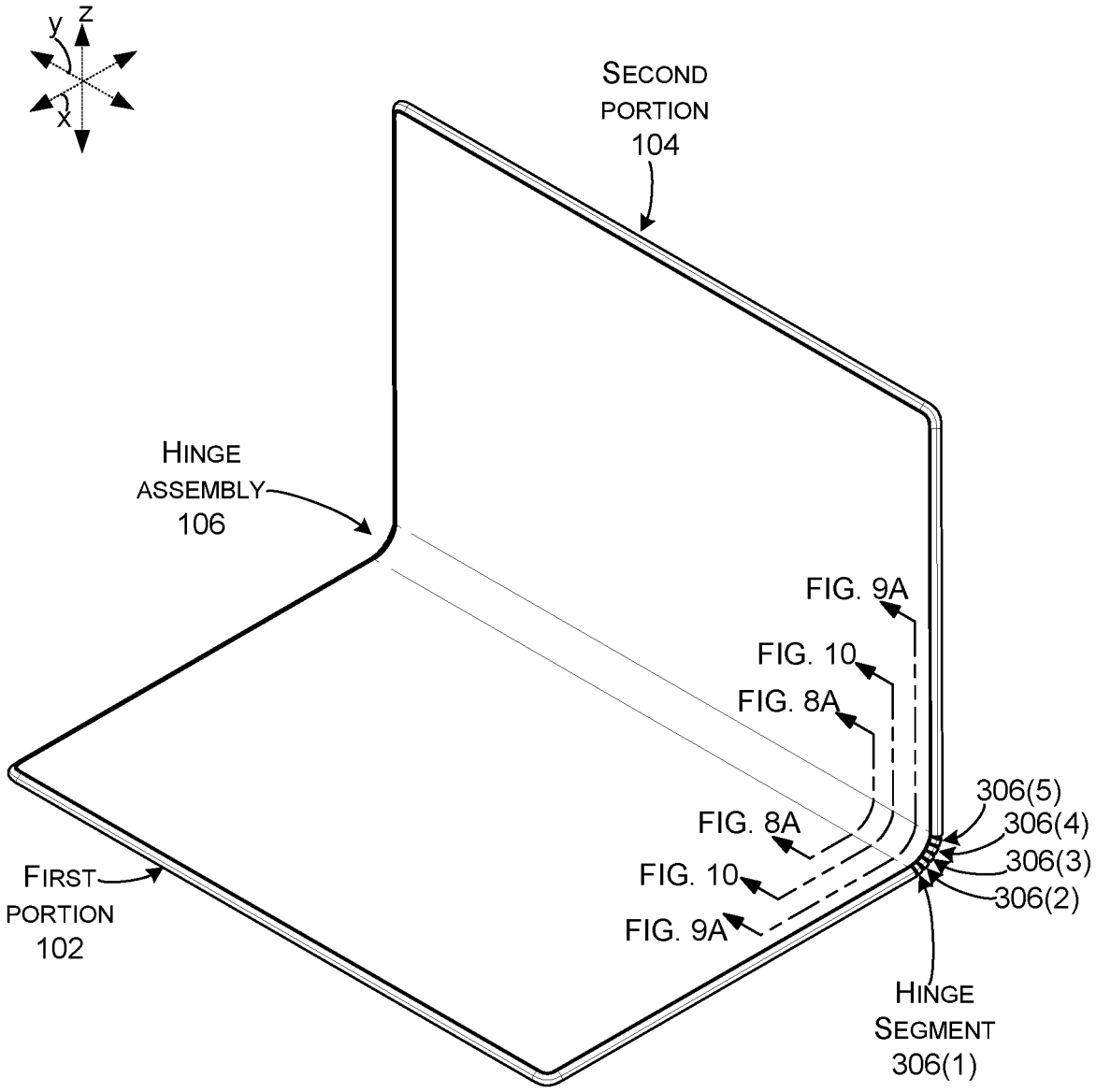

y
z
x
SECOND PORTION 104
HINGE ASSEMBLY 106
FIG. 9A
FIG. 10
FIG. 8A
306(5)
306(4)
306(3)
306(2)
FIG. 8A
FIG. 10
FIG. 9A
FIRST PORTION 102
HINGE SEGMENT 306(1)

FIG. 7

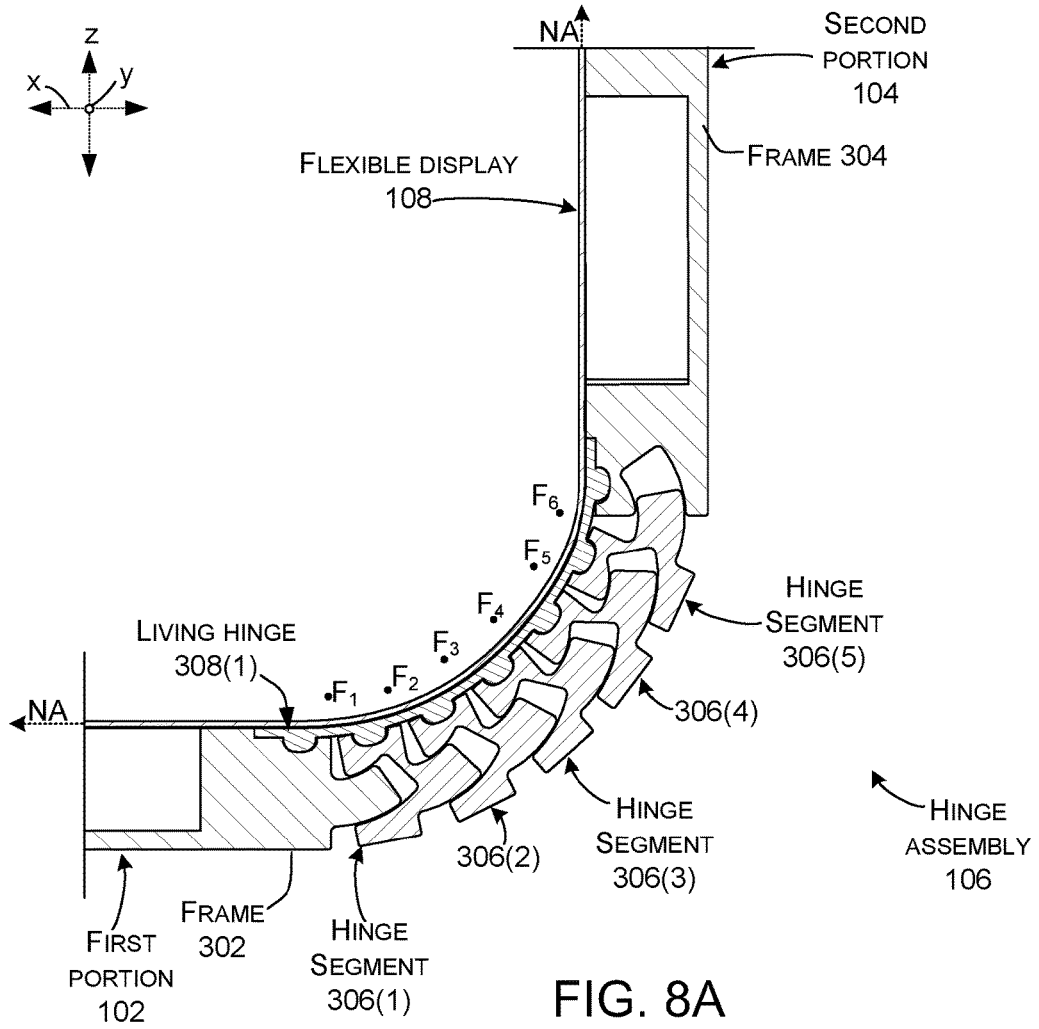
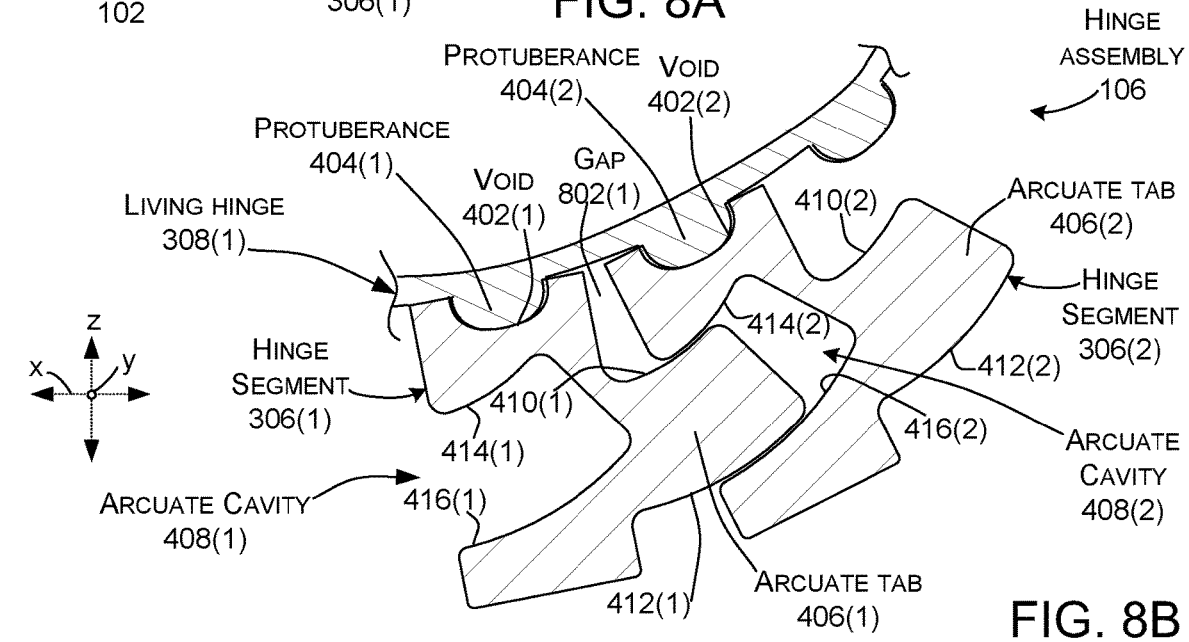

z
x
y
NA
SECOND PORTION 104
FRAME 304
FLEXIBLE DISPLAY 108
F6
F5
F4
F3
F2
F1
HINGE SEGMENT 306(5)
LIVING HINGE 308(1)
NA
306(4)
HINGE SEGMENT 306(3)
HINGE ASSEMBLY 106
306(2)
FRAME 302
FIRST PORTION 102
HINGE SEGMENT 306(1)

FIG. 8A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VOID 402(2)
PROTUBERANCE 404(1)
GAP 802(1)
VOID 402(1)
LIVING HINGE 308(1)
410(2)
ARCUATE TAB 406(2)
HINGE SEGMENT 306(2)
z
x
y
414(2)
412(2)
HINGE SEGMENT 306(1)
410(1)
416(2)
ARCUATE CAVITY 408(2)
414(1)
ARCUATE CAVITY 408(1)
416(1)
412(1)
ARCUATE TAB 406(1)

FIG. 8B

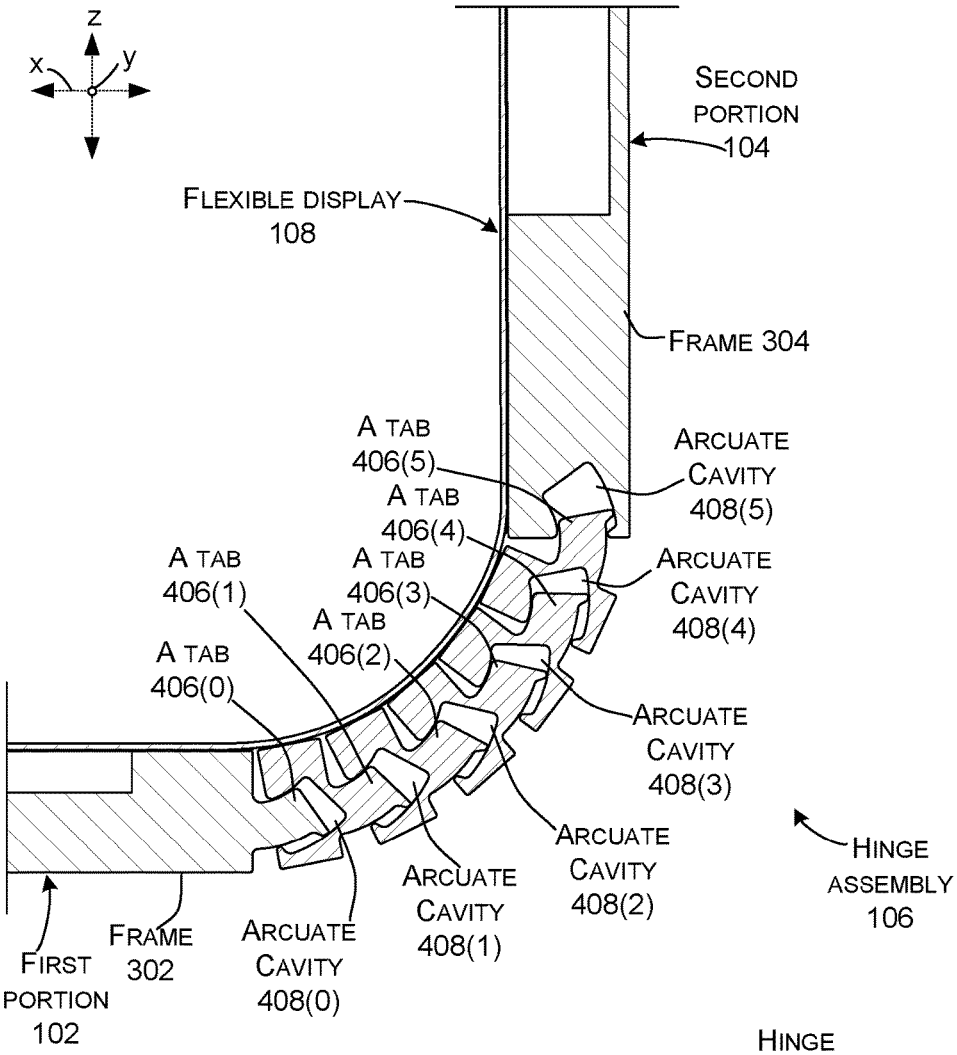

z
x
y
SECOND PORTION 104
FLEXIBLE DISPLAY 108
FRAME 304
A TAB 406(5)
ARCUATE CAVITY 408(5)
A TAB 406(4)
A TAB 406(1)
A TAB 406(3)
ARCUATE CAVITY 408(4)
A TAB 406(2)
A TAB 406(0)
ARCUATE CAVITY 408(3)
ARCUATE CAVITY 408(2)
HINGE ASSEMBLY 106
ARCUATE CAVITY 408(1)
FRAME 302
ARCUATE CAVITY 408(0)
FIRST PORTION 102

FIG. 9A

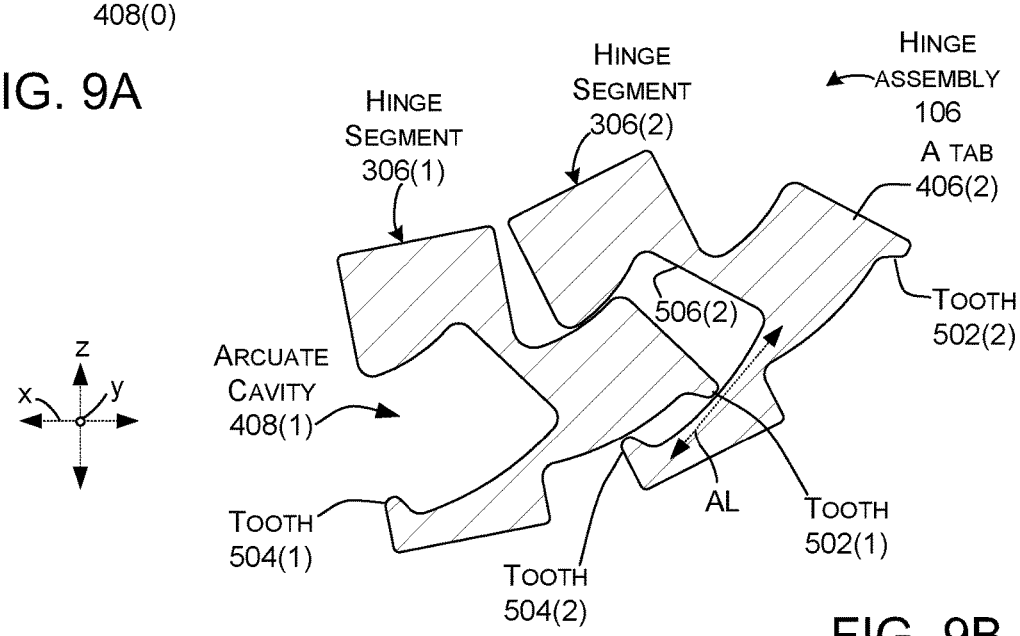

HINGE SEGMENT 306(1)
HINGE SEGMENT 306(2)
HINGE ASSEMBLY 106
A TAB 406(2)
TOOTH 502(2)
506(2)
z
x
y
ARCUATE CAVITY 408(1)
AL
TOOTH 504(1)
TOOTH 502(1)
TOOTH 504(2)

FIG. 9B

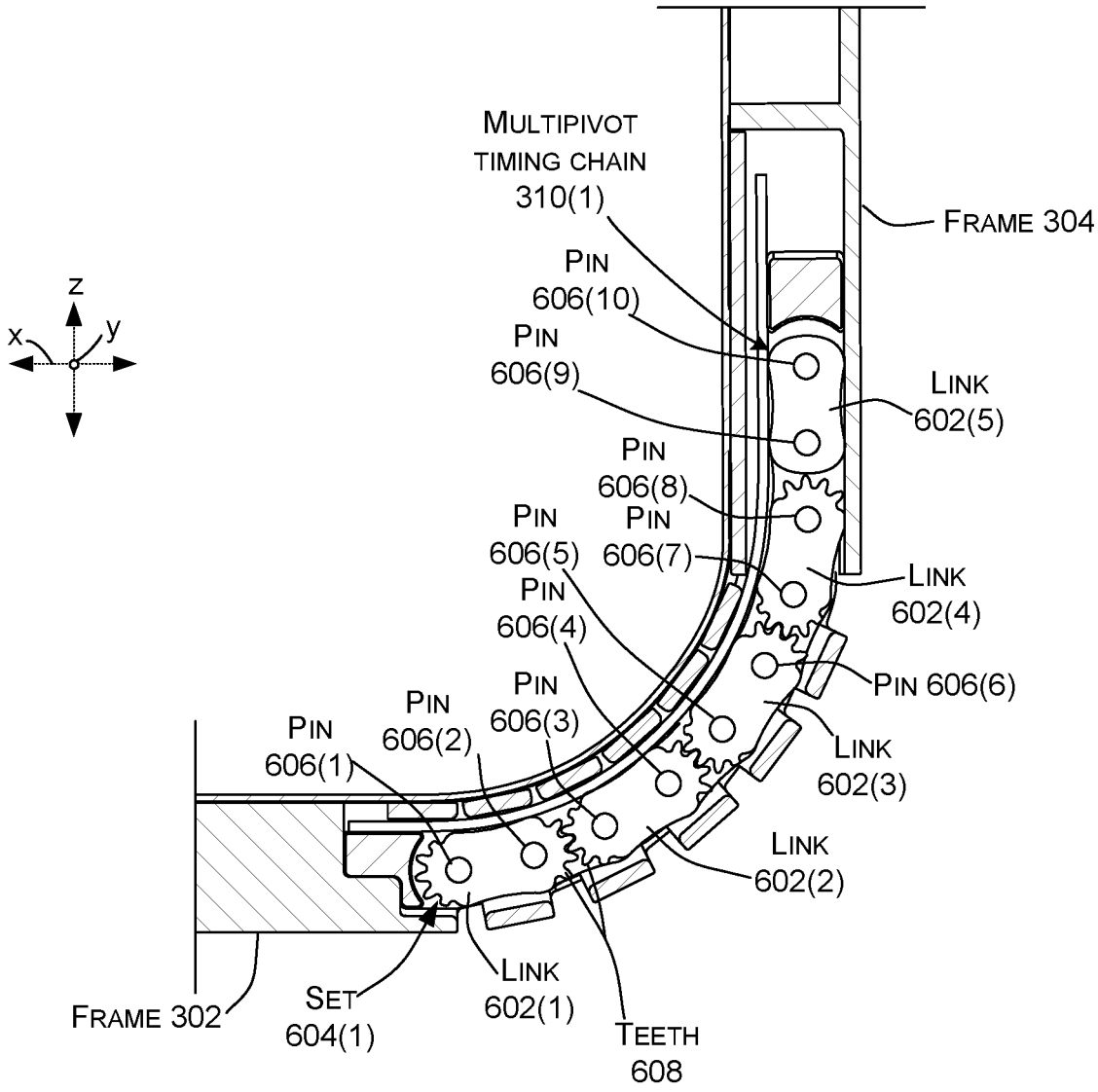

MULTIPIVOT
TIMING CHAIN
310(1)
FRAME 304
PIN
606(10)
PIN
606(9)
LINK
602(5)
PIN
606(8)
PIN
606(5)
PIN
606(7)
LINK
602(4)
PIN
606(4)
PIN 606(6)
PIN
606(3)
PIN
606(2)
PIN
606(1)
LINK
602(3)
LINK
602(2)
LINK
602(1)
SET
604(1)
FRAME 302
TEETH
608
z
x
y

FIG. 10

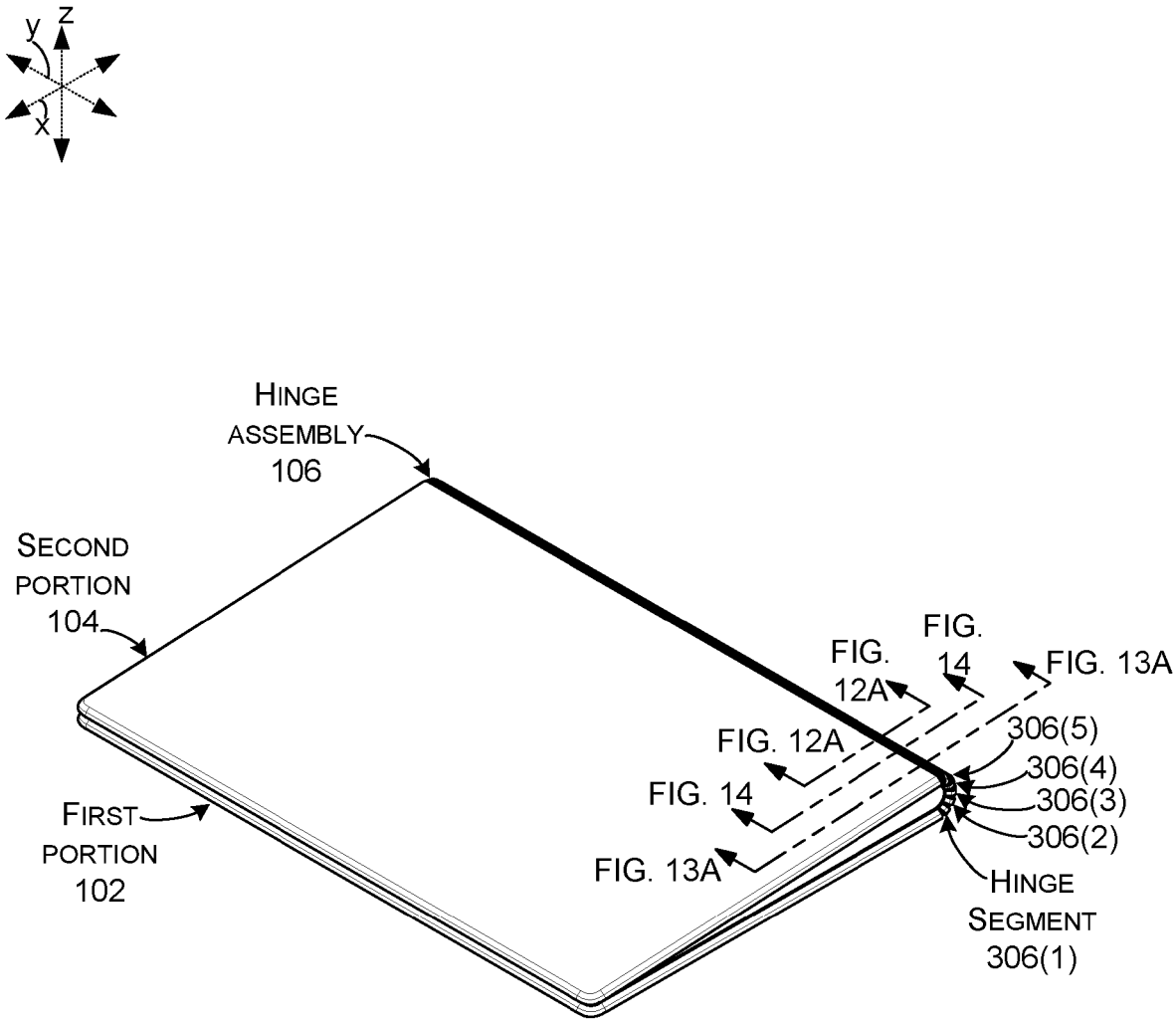
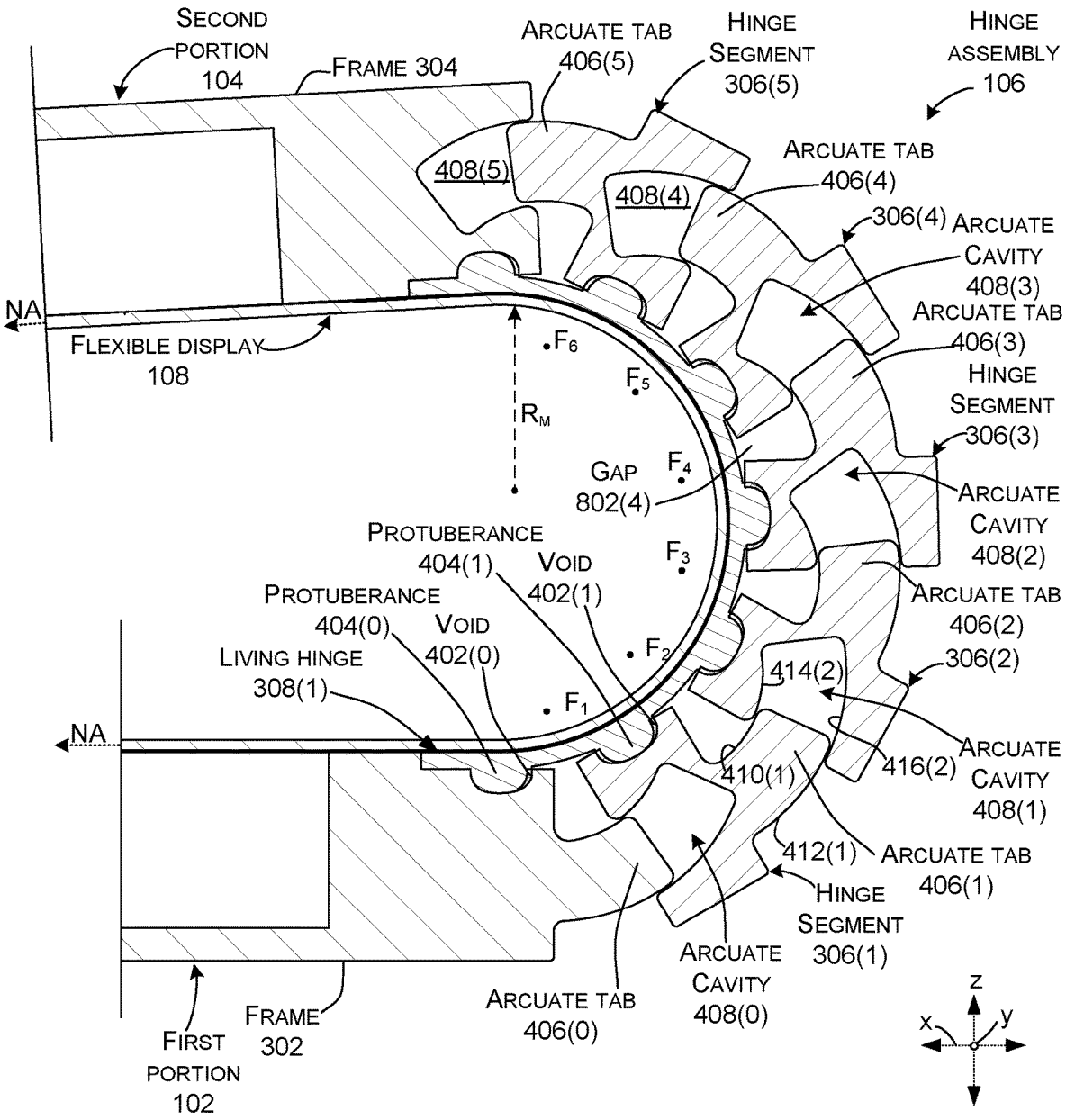

y
z
x
HINGE ASSEMBLY 106
SECOND PORTION 104
FIRST PORTION 102
FIG. 12A
FIG. 14
FIG. 13A
306(5)
306(4)
306(3)
306(2)
HINGE SEGMENT 306(1)

FIG. 11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HINGE SEGMENT 306(5)
HINGE ASSEMBLY 106
ARCUATE TAB 406(4)
408(5)
408(4)
306(4)
ARCUATE CAVITY 408(3)
NA
FLEXIBLE DISPLAY 108
ARCUATE TAB 406(3)
F_6
F_5
R_M
HINGE SEGMENT 306(3)
GAP 802(4)
F_4
ARCUATE CAVITY 408(2)
PROTUBERANCE 404(1)
VOID 402(1)
F_3
PROTUBERANCE 404(0)
VOID 402(0)
ARCUATE TAB 406(2)
306(2)
LIVING HINGE 308(1)
F_2
414(2)
F_1
NA
ARCUATE CAVITY 408(1)
410(1)
416(2)
412(1)
ARCUATE TAB 406(1)
HINGE SEGMENT 306(1)
ARCUATE CAVITY 408(0)
ARCUATE TAB 406(0)
FRAME 302
FIRST PORTION 102
z
x
y

FIG. 12A

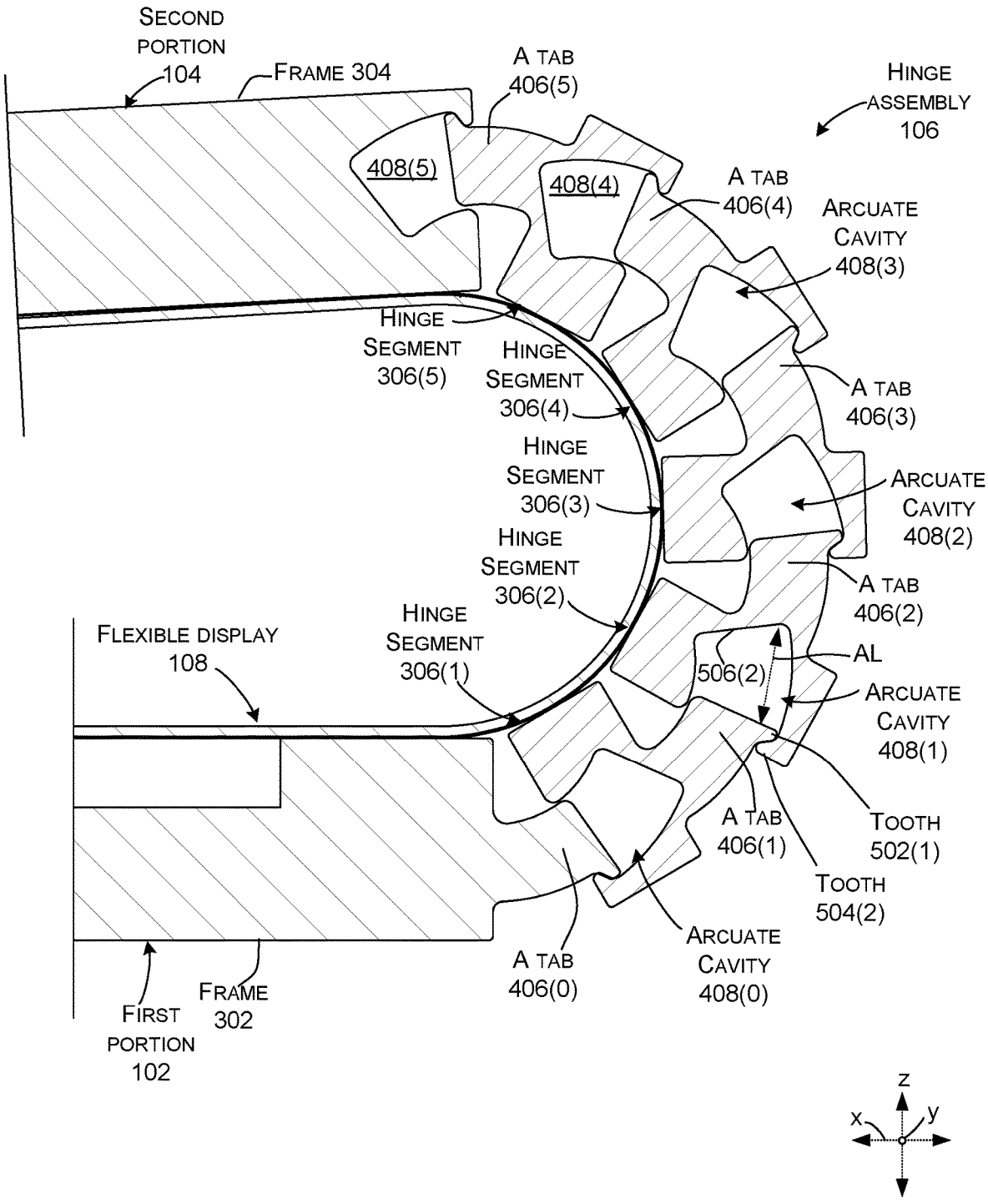
SECOND PORTION 104
FRAME 304
A TAB 406(5)
HINGE ASSEMBLY 106
408(5)
408(4)
A TAB 406(4)
ARCUATE CAVITY 408(3)
HINGE SEGMENT 306(5)
HINGE SEGMENT 306(4)
A TAB 406(3)
HINGE SEGMENT 306(3)
ARCUATE CAVITY 408(2)
HINGE SEGMENT 306(2)
A TAB 406(2)
FLEXIBLE DISPLAY 108
HINGE SEGMENT 306(1)
506(2)
AL
ARCUATE CAVITY 408(1)
A TAB 406(1)
TOOTH 502(1)
TOOTH 504(2)
A TAB 406(0)
ARCUATE CAVITY 408(0)
FRAME 302
FIRST PORTION 102
z
x
y

FIG. 13A

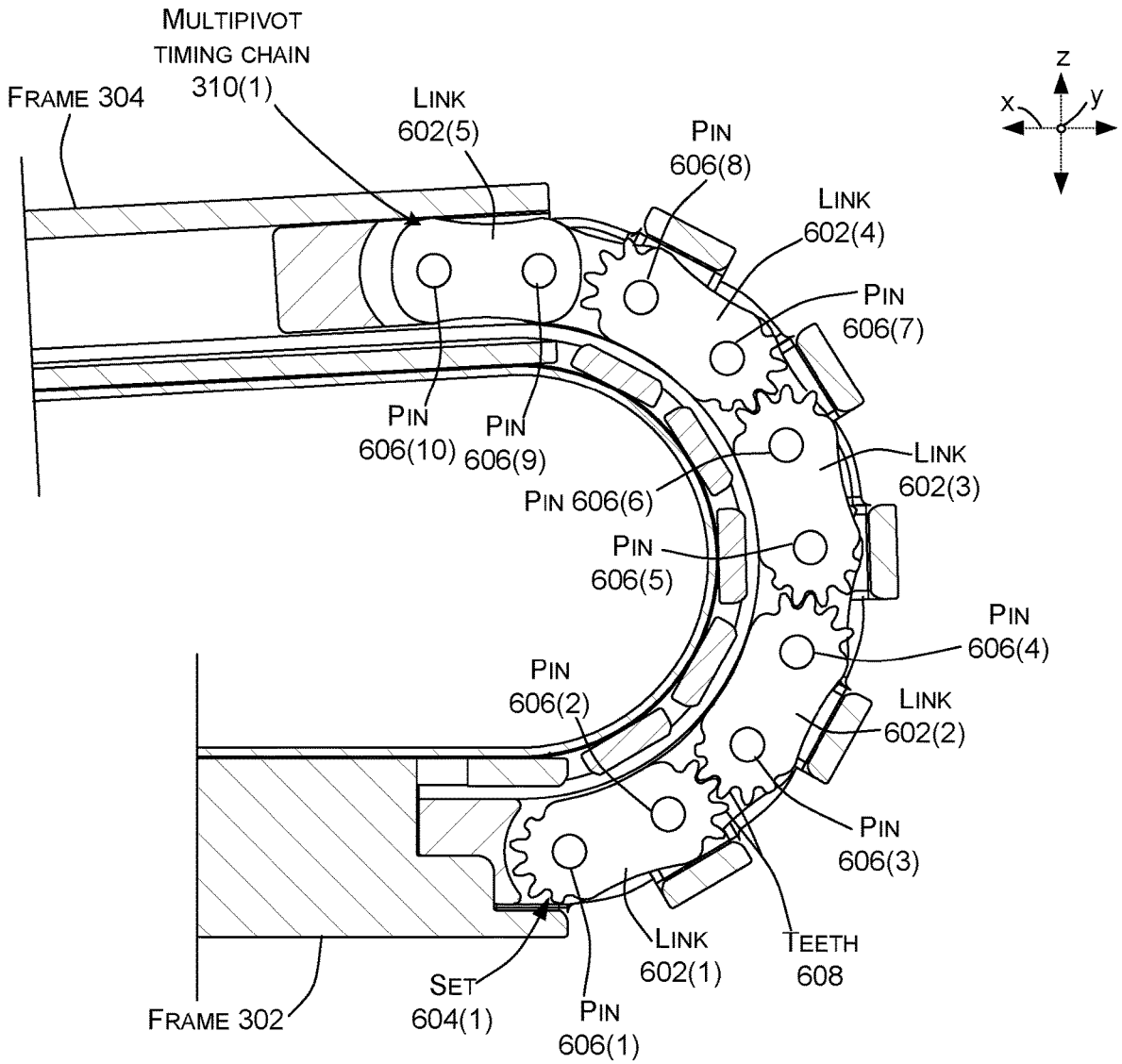
MULTIPIVOT
TIMING CHAIN
310(1)
FRAME 304
LINK
602(5)
PIN
606(8)
LINK
602(4)
PIN
606(7)
PIN
606(10)
PIN
606(9)
PIN 606(6)
LINK
602(3)
PIN
606(5)
PIN
606(4)
PIN
606(2)
LINK
602(2)
PIN
606(3)
LINK
602(1)
TEETH
608
SET
604(1)
PIN
606(1)
FRAME 302
z
x
y

FIG. 14

FLEXIBLE DISPLAY HINGED DEVICE

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate implementations of the concepts conveyed in the present document. Features of the illustrated implementations can be more readily understood by reference to the following description taken in conjunction with the accompanying drawings. Like reference numbers in the various drawings are used wherever feasible to indicate like elements. Further, the left-most numeral of each reference number conveys the FIG. and associated discussion where the reference number is first introduced.

FIGS. **1**A-**1**C, **2**, **3**A, **7**, and **11** are perspective views of an example hinged device that can avoid imparting stress forces on a flexible display in accordance with some implementations of the present concepts.

FIG. **3**B is an exploded perspective view of an example hinged device that can avoid imparting stress forces on a flexible display in accordance with some implementations of the present concepts.

FIGS. **4**A, **4**C, **5**A, **5**C, **6**, **8**A, **8**B, **9**A, **9**B, **10**, **12**A, **13**A, and **14** are sectional views of an example hinged device that can avoid imparting stress forces on a flexible display in accordance with some implementations of the present concepts.

FIGS. **4**B and **5**B are exploded sectional views of an example hinged device that can avoid imparting stress forces on a flexible display in accordance with some implementations of the present concepts.

DESCRIPTION

The present concepts relate to hinged devices employing flexible displays. A hinge assembly can rotatably secure two device portions and a single flexible display can span the two device portions. Such devices have been previously contemplated. However, in practice rotation of the first and second portions subjected the flexible display to undesirable stress forces, such as tension and/or compression. To address these problems, previous solutions included mechanisms to allow one end of the hinge or one end of the flexible display to slide during rotation to reduce undesirable forces imparted on the flexible display. These solutions came with their own shortcomings, including complexity and unreliability, among others. The present implementations can employ a self-adjusting arcuate hinge design that can automatically adjust its length during rotation and can maintain the flexible display on the neutral axis during rotation. Flexible displays have advantages over rigid displays, but can be susceptible to damage. Thus, these implementations solve a technical problem of maintaining the flexible display in a neutral environment throughout the range of rotation of the first and second portions.

Introductory FIGS. **1**A-**1**C show an example device **100** that has first and second portions **102** and **104** that are rotatably secured together by a hinge assembly **106**. A flexible display **108** is secured to the first and second portions **102** and **104**. In this case, the flexible display is fixedly secured to both the first and second portions (e.g., the flexible display does not slide relative to the first and second portions during rotation). This configuration avoids relative movement between the device portions and the flexible display that could cause reliability problems, such as short circuits in circuitry connected to the flexible display.

The radius hinge assembly **106** can allow the computing device **100** to rotate through a range of rotation from a deployed or open orientation (e.g., 180-degrees in this implementation) of FIG. **1**A, through a partially open orientation of FIG. **1**B, to the storage or closed orientation of FIG. **1**C. In some implementations, the closed orientation can be about zero degrees (e.g., in a range of +/− a few degrees, such as 5-degrees). In the illustrated implementation, the closed orientation is about −2-degrees).

The deployed orientation of FIG. **1**A can provide the user with a relatively large display area while the storage orientation can provide a smaller device footprint while protecting the flexible display **108** from damage. Intermediate orientations can be utilized for various purposes. For instance, the user may want to use the device in a similar fashion to a notebook computer in the orientation shown in FIG. **1**B. The hinge assembly **106** can maintain the device in these various orientations unless acted upon by the user to change the orientation.

The device **100** is shown in a manner to emphasize the flexible display **108** and the hinge assembly **106**. However, the device may include other components. For instance, in one case, the first and second portions can be manifest as housings. Electronic components, such as processors and/or storage, may be positioned on and/or in the housing and may be interconnected by conductors extending between the two portions and/or to the flexible display. A myriad of device implementations is contemplated. For instance, the device can be manifest as an e-reader, a laptop computer, a tablet computer, a smart phone computer, a wearable smart device, a display device, a home appliance, a component of an airline seat, and/or a component of a vehicle, among other implementations.

FIG. **2** shows device **100** in an open orientation similar to FIG. **1**A. A region of the flexible display **108** is removed to show underlying components. As indicated, the underlying components are shown in an enlarged view in FIG. **3**A.

FIGS. **3**A and **3**B collectively show hinge assembly **106** and proximate regions of first and second portions **102** and **104**. FIG. **3**B is an exploded view that is similar to, but not exactly corresponding to FIG. **3**A. For instance, FIG. **3**B shows flexible display **108**, which is not shown in FIG. **3**A.

In this implementation, the first portion **102** can include a housing or frame **302** and the second portion **104** can include a housing or frame **304**. The hinge assembly **106** can include multiple hinge segments **306**, living hinges **308**, and multi-pivot timing chains **310**. (Only living hinge **308**(**1**) and multi-pivot timing chains **310**(**1**) are shown in these close-up views, but they are illustrative of these elements generally that may occur along a length of the hinge assembly **106** between the first and second portions **102** and **104** (e.g., along they reference axis)). In this case, five hinge segments **306** are employed, but less than five or more than five hinge segments can be employed in other implementations. The hinge segments **306** can be elongate (in this case, as long as the first and second portions) and run parallel to one another and to the first and second portions (e.g., parallel to the y-reference axis).

The hinge segments **306** can define passages **312** (only one of which (**312**(**5**)) is designated to avoid clutter on FIG. **3**B). The multi-pivot timing chain **310** can extend through the passages **312** and be secured to the first and second portions **102** and **104**. In this example, multi-pivot timing chain **310** is fixedly secured to the first portion **102** with a fastener **314**. The multi-pivot timing chain **310** is slideably secured to the second portion **104**. In this case, the frame **304** defines a channel **316** that receives the multi-pivot timing

chain **310**. A plate **318** can be fastened to the frame **304** to retain the multi-pivot timing chain **310**. The multi-pivot timing chain can synchronize rotation between the hinge segments (e.g., provide simultaneous and even rotation between the hinge segments). This multi-pivot timing chain is described in more detail below relative to FIGS. **6**, **10**, and **14**.

The living hinge **308**(**1**) can be secured to the first portion **102**, the hinge segments **306**, and the second portion **104**. The first and second portions **102** and **104** as well as hinge segments **306** can define voids **402** (not all of which are specifically designated to avoid clutter on the drawing page) facing the flexible display **108**. In this case, the living hinge **308**(**1**) can be secured to the hinge segments **306** by extending into the voids **402**. Specifically, protuberances **404** (not all of which are specifically designated to avoid clutter on the drawing page) of the living hinge **308**(**1**) can extend into the voids **402** to maintain association between the living hinge **308**(**1**) and the hinge segments (e.g., the living hinge is secured to the hinge segments, but limited movement can occur between the living hinge and the hinge segments). This aspect will be described in more detail below relative to FIGS. **8**A, **8**B, and **12**A.

The living hinge **308**(**1**) can be implemented in various forms. In one case, the living hinge comprises elastomeric materials, such as a monomer or a polymer. In other cases, the living hinge can be formed of multiple materials. For instance, flexible material can be formed around a metal or fibrous mesh. In one implementation, the living hinge **308** is a sheet of flexible elastomeric material.

The living hinge **308**(**1**) in combination with the arcuate hinge segments **306** can allow the hinge assembly **106** to rotate while maintaining the neutral axis (NA) at (e.g., co-extensive with), or proximate to, the flexible display **108** (see FIG. **4**A). This aspect is discussed and illustrated relative to FIGS. **4**A, **8**A, and **12**A.

Note also that the hinge segments **306** may at first glance appear to simply be cosmetic covers for the hinge assembly **106**. Such is not the case, the hinge segments **306** (in combination with the living hinge **308**) provide the hinge functionality. Further, as will become apparent below in the sectional views (such as FIG. **4**B), outer surfaces **320** (designated relative to hinge segment **306**(**1**)) provide strength and functionality to the hinge segments to such an extent that in some implementations, the hinge segments can be viewed as exoskeletal hinge segments **322** (designated relative to hinge segment **306**(**1**)). In such cases, the exoskeletal hinge segments derive their strength from the outer surfaces **320** and can be hollow and/or can have interior supportive material.

As designated in the exploded view of FIG. **4**B, the hinge segments **306** can define arcuate tabs **406** and arcuate cavities **408**. (Note also, to integrate the hinge assembly **106** with the first and second portions **102** and **104**, the first arcuate tab **406**(**0**) is defined by the first portion **102** and the last arcuate cavity **408**(**6**) is defined by the second portion **104**, but other configurations are contemplated). The arcuate tab **406** of an individual hinge segment can interact with, and travel in, the arcuate cavity **408** of the adjacent hinge segment during the range of rotation. In this case, the arcuate tabs **406** can include first and second arcuate sidewalls **410** and **412** and the arcuate cavity includes third and fourth arcuate sidewalls **414** and **416**. As indicated in FIG. **4**C, the first arcuate sidewall **410**, the second arcuate sidewall **412**, the third arcuate sidewall **414**, and the fourth arcuate sidewall **416** share a common focus F. See for instance, arc A_1 representing arcuate sidewalls **410** and **414** and arc A_2 representing arcuate sidewalls **412** and **416**, that have focus F_1.

Interaction of adjacent arcuate tabs **406** and arcuate cavities **408** can define the arcuate path of the hinge assembly **106** during rotation. For instance, interaction of the first sidewall **410** and the third sidewall **414** can define a path of the hinge assembly **106** (see for instance. FIG. **4**B first sidewall **410**(**1**) and third sidewall **414**(**2**). Ultimately, when taken in combination, the arcuate path of the individual hinge segments **306** can define a minimum bend radius experienced by the flexible display during the range of rotation between the first portion **102** and the second portion **104**. The minimum bend radius is indicated in FIG. **12**A and can be understood by comparing FIGS. **4**A, **8**A, and **12**A.

FIGS. **5**A-**5**C show another cross-section through hinge assembly **106** as indicated in FIG. **3**A. These views are similar to views **4**A-**4**C, respectively. Here, the arcuate tab **406** of an individual hinge segment includes a tooth **502** and the arcuate cavity **408** of an adjacent hinge segment defines (or is defined by) an opposing tooth **504**. Interaction of these teeth **502** and **504** can retain the arcuate tab **406** in the adjacent arcuate cavity **408**. Also, an arc length 'AL' between the tooth **504** and an end wall **506** of the arcuate cavity **408** can define a range of rotation between the two adjacent hinge segments **306**. Accordingly, the range of rotation of the hinge assembly **106** is the sum of the range of rotations AL defined by the individual hinge segments **306**. From another perspective, the sum of the arc lengths AL can define the hinge assembly's range of rotation.

As indicated in FIG. **3**A, FIG. **6** is a cross-section through the hinge assembly **106** that shows additional details about the multi-pivot timing chain **310**(**1**). The multi-pivot timing chain can provide timing to the hinge assembly **106**. The multi-pivot timing chain can include multiple links **602** arranged in linear sets **604**. In this example, the links are arranged in two offset linear sets with set **604**(**1**) toward the reader and **604**(**2**) away from the reader and shown in ghost (dotted lines). Linear set **604**(**1**) includes links **602**(**1**)-**602**(**5**) and linear set **604**(**2**) includes links **602**(**6**)-**602**(**7**). (Only a partial set **604**(**2**) is shown to avoid obfuscating the forward set **604**(**1**) with clutter on the drawing page). The links can be arranged on axis pins **606**.

Links **602** can include teeth **608**. Teeth of adjacent links can intermesh. Intermeshing of the teeth **608** can provide uniform simultaneous rotation around the axis pins **606**. The intermeshing teeth can also provide friction, which provides resistance to rotation. The resistance to rotation can help maintain the first and second portions **102** and **104** in a specific orientation unless the user exerts a force to rotate the first and second portions relative to one another. The number of sets can be increased and/or decreased to adjust the resistance to rotation.

FIGS. **7**-**10** collectively show the hinge assembly in the 90-degree orientation. FIGS. **8**A-**10** are similar views to FIGS. **4**A-**6** except that there is not an exploded view corresponding to FIG. **4**B.

Looking at FIGS. **8**A and **8**B, the hinge segments **306** are rotating relative to their foci (F_1-F_6). More specifically, arcuate tabs **406** are traveling in adjacent arcuate cavities **408**. On a global scale, the living hinge **308**(**1**) can maintain the first portion **102**, hinge segments **306**, and second portion **104**. However, on a granular scale, the living hinge is allowing subtle relative movement between adjacent hinge segments. For instance, gaps **802** (**802**(**1**) designated in FIG. **8**B) have opened between adjacent hinge segments as they (the hinge segments) move along their arcuate paths.

Compare to FIG. **4**A where the adjacent hinge segments were contacting one another (e.g., no gap). This localized movement can be facilitated by the interactions of the protuberances **404** in their respective voids **402**. Further, due to the arcuate nature of the tabs **406** and the cavities **408**, the width of the gaps increases with increasing distance from the flexible display **108**.

FIG. **9**B shows the adjacent hinge segments are about half-way along their arc lengths AL as defined by the position of tooth **502**(**1**) between end wall **506**(**2**) and tooth **504**(**2**).

FIG. **10** shows intermeshing teeth **608** timing rotation around the axis pins **606** so that simultaneous and equal rotation occurs around individual axis pins.

FIGS. **11-14** collectively show the hinge assembly in the closed orientation. The views of FIGS. **11-14** are otherwise similar to those of FIGS. **7-10**.

FIG. **12**A shows the hinge segments **306** continuing to rotate around their respective foci (F_1-F_6). The living hinge **308** continues to hold the first portion **102**, the hinge segments **306** and the second portion **104** together, while allowing relative movement between adjacent hinge segments. Specifically, the living hinge's protuberances **404** can interact with the hinge segment's voids **402** in a ball and socket fashion to allow localized relative movement resulting in increased dimensions of gaps **802** (**802**(**4**) designated in FIG. **12**A). When viewed collectively, the gaps indicate that the hinge assembly has lengthened as the hinge assembly is rotated from the open orientation to the closed orientation. Further, the lengthening increases with increasing distance from the flexible display (e.g., from a common focus of the bend radius of the flexible display). This arcuate or radial expansion helps to ensure that the common focus of the flexible display's bend radius occurs on an opposite side of the flexible display from the hinge segments **306** though the range of rotation. Further, the arcuate or radial expansion can ensure that the flexible display will not be exposed to stretching or compressing forces during the range of rotation.

At this point (e.g., the closed orientation), the rigid nature of the hinge assembly's hinge segments **306** maintains a minimum bend radius (R_m) that the flexible display experiences during the range of rotation. The neutral axis (NA) continues to be co-extensive with the flexible display **108**.

FIG. **13**A shows the arcuate tabs **406** have completed their arc lengths AL through the adjacent arcuate cavities **408**. For instance, FIG. **5**C showed arcuate tab **406**(**1**) against the end wall **506**(**2**). FIG. **9**B showed an intervening position. Now, in FIG. **13**A the tooth **502**(**1**) is engaging tooth **504**(**2**), which blocks further relative rotation between hinge segment **306**(**1**) and hinge segment **306**(**2**). In this case, approximately 30 degrees of rotation has occurred between frame **302** and hinge segment **306**(**1**) as well as approximately 30 degrees of rotation between each of the adjacent hinge segments **306**(**1**)-**306**(**5**), and between hinge segment **306**(**5**) and second portion **104**. This produces a collective rotation of about 180 degrees between the open orientation of FIGS. **3A-6** and the closed orientation of FIGS. **11-14**.

FIG. **14** shows the intermeshing teeth **608** of adjacent links **602** continuing to provide synchronous (e.g., simultaneous and uniform) rotation around the axis pins **606**. This facilitates synchronous rotation around the hinge segments **306** of FIG. **13**A as rotation of the first and second portions proceed from the open orientation to the closed orientation.

The hinge assemblies described above can employ an arcuate shape that grows and shrinks by an amount dependent on distance from the focus of the bend radius of the flexible display. As such, the hinge assembly grows and shrinks around the flexible display during rotation while maintaining the flexible display coextensively to the neutral axis. Accordingly, no sliding of the hinge assembly or the flexible display is required to protect the display during rotation.

Individual elements of the hinge assembly can be made from various materials, such as sheet metals, die cast metals, machined parts, and/or polymers, such as molded plastics, among others, or any combination of these materials.

Any type of flexible display material(s) can be utilized. Flexible display technologies are rapidly developing and the present concepts can be applied to any of these technologies, such as but not limited to flexible electronic paper based displays, and/or flexible organic light-emitting diode (OLED)-based displays, among others.

Example Methods

Various methods of manufacture, assembly, and use for computing devices, hinge assemblies, and/or flexible displays are contemplated beyond those shown above relative to FIGS. **1-14**.

Additional Examples

Various device examples are described above. Additional examples are described below. One example includes a device comprising a first portion and a second portion that are rotatably secured by a hinge assembly from a closed orientation through a range of rotation to an open orientation. A flexible display is fixedly secured to the first and second portions, and the hinge assembly consists of a first hinge segment that defines an arcuate tab that travels in an arcuate cavity of an adjacent second hinge segment during the range of rotation.

Another example can include any of the above and/or below examples where the device consists of a living hinge secured to the first portion, the first hinge segment, the second hinge segment, and the second portion.

Another example can include any of the above and/or below examples where the living hinge comprises a sheet of flexible elastomeric material.

Another example can include any of the above and/or below examples where the first hinge segment and the second hinge segment define voids facing the flexible display.

Another example can include any of the above and/or below examples where the living hinge is secured to the first hinge segment and the second hinge segment by extending into the voids.

Another example can include any of the above and/or below examples where the device further consists of a multi-pivot timing chain extending through the first and second hinge segments and secured to the first portion and the second portion.

Another example can include any of the above and/or below examples where the multi-pivot timing chain is fixedly secured to the first portion and slideably secured to the second portion.

Another example can include any of the above and/or below examples where the multi-pivot timing chain synchronizes rotation between the first and second hinge segments.

Another example can include any of the above and/or below examples where the multi-pivot timing chain includes

intermeshing gears that cause simultaneous and equal rotation around each hinge axis of the multi-pivot timing chain.

Another example can include any of the above and/or below examples where the first and second hinge segments comprise hollow exoskeletons.

Another example can include any of the above and/or below examples where the arcuate tab of the first hinge segment includes a tooth and the arcuate cavity of the second hinge segment defines an opposing tooth.

Another example can include any of the above and/or below examples where an arc length between the opposing tooth and an end wall of the arcuate cavity define a range of rotation between the first hinge segment and the second hinge segment.

Another example can include any of the above and/or below examples where engagement of the tooth and the opposing tooth retain the arcuate tab in the arcuate cavity.

Another example can include any of the above and/or below examples where the closed orientation comprises negative two degrees and the open orientation comprises one hundred and eighty degrees.

Another example includes a device comprising a first portion and a second portion, as well as a first exoskeletal hinge segment secured to the first portion and a second exoskeletal hinge segment secured to the second portion, the first exoskeletal hinge segment defining an arcuate tab that travels in an arcuate cavity defined by the second exoskeletal hinge segment to allow relative rotation between the first and second portions.

Another example can include any of the above and/or below examples where the arcuate tab includes first and second arcuate sidewalls and the arcuate cavity includes third and fourth arcuate sidewalls.

Another example can include any of the above and/or below examples where the first arcuate sidewall, the second arcuate sidewall, the third arcuate sidewall, and the fourth arcuate sidewall share a common focus.

Another example can include any of the above and/or below examples where a device further comprises a single flexible display fixedly secured to the first portion and to the second portion.

Another example can include any of the above and/or below examples where the common focus is on an opposite side of the flexible display as the first and second exoskeletal hinge segments.

Another example can include any of the above and/or below examples where interaction of the first sidewall and the third sidewall define a minimum bend radius experienced by the single flexible display during a range of rotation between the first portion and the second portion.

Another example includes a device comprising a first portion and a second portion rotatably secured by a hinge assembly, a flexible display fixedly secured to the first and second portions, and the hinge assembly comprising a set of elongate hinge segments, adjacent hinge segment moving arcuately relative to one another during rotation of the first and second portions.

CONCLUSION

Although techniques, methods, devices, systems, etc., pertaining to hinged devices that employ flexible displays are described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as exemplary forms of implementing the claimed methods, devices, systems, etc.

The invention claimed is:

1. A device, comprising:

a first portion and a second portion that are rotatably secured by a hinge assembly through a range of rotation from a closed orientation to an open orientation; and

a flexible display fixedly secured to the first and second portions;

the hinge assembly comprising a first hinge segment that defines an arcuate tab that travels in an arcuate cavity of an adjacent second hinge segment during the range of rotation, the first portion, the second portion, the first hinge segment, and the second hinge segment defining respective voids facing the flexible display, and

the hinge assembly comprising a hinge secured to the first portion, the first hinge segment, the second hinge segment, and the second portion, the hinge defining protuberances having a partial cylindrical shape that extend into the respective voids and interact with the respective voids in a ball-and-socket fashion.

2. The device of claim **1**, further comprising a multi-pivot timing chain extending through the first and second hinge segments and secured to the first portion and the second portion.

3. The device of claim **2**, wherein the multi-pivot timing chain is fixedly secured to the first portion and slideably secured to the second portion.

4. The device of claim **2**, wherein the multi-pivot timing chain synchronizes rotation between the first and second hinge segments.

5. The device of claim **2**, wherein the multi-pivot timing chain includes intermeshing gears that cause simultaneous and equal rotation around each hinge axis of the multi-pivot timing chain.

6. The device of claim **1**, wherein the arcuate tab of the first hinge segment includes a tooth and the arcuate cavity of the second hinge segment defines an opposing tooth.

7. The device of claim **6**, wherein an arc length between the opposing tooth and an end wall of the arcuate cavity define a range of rotation between the first hinge segment and the second hinge segment.

8. The device of claim **6**, wherein engagement of the tooth and the opposing tooth retain the arcuate tab in the arcuate cavity.

9. The device of claim **1**, wherein the arcuate cavity includes two arcuate sidewalls that are parallel.

10. The device of claim **1**, wherein the hinge assembly maintains a neutral axis coextensively with the flexible display through the range of rotation.

11. The device of claim **1**, wherein the hinge assembly creates a gap between the first hinge segment and the second hinge segment and thereby increases a length of a surface of the hinge assembly facing the flexible display as the hinge assembly is rotated from the open orientation to the closed orientation.

12. A device, comprising:

a first portion and a second portion rotatably secured by a hinge assembly; and,

a flexible display fixedly secured to the first and second portions;

the hinge assembly comprising a set of elongate hinge segments, adjacent hinge segments moving arcuately relative to one another during rotation of the first and second portions, at least one of the adjacent hinge segments having an arcuate cavity that receives an

individual adjacent hinge segment and includes two arcuate sidewalls, the first portion, the second portion, and the set of elongate hinge segments defining respective voids facing the flexible display, and

the hinge assembly comprising a hinge secured to the first portion, the second portion, and the set of elongate hinge segments, the hinge defining protuberances having a partial cylindrical shape that extend into the respective voids and interact with the respective voids in a ball-and-socket fashion.

13. The device of claim **12**, further comprising:

a multi-pivot timing chain that synchronizes rotation of the hinge segments.

14. The device of claim **13**, wherein the multi-pivot timing chain includes multiple linear sets of links.

15. The device of claim **14**, wherein the links include intermeshing teeth and the links rotate simultaneously as the first portion and the second portion rotate.

16. The device of claim **13**, wherein the multi-pivot timing chain extends through the hinge segments.

17. The device of claim **12**, wherein the two arcuate sidewalls are equidistant.

18. The device of claim **12**, wherein the two arcuate sidewalls share a common focus.

19. The device of claim **12**, wherein the hinge assembly maintains a neutral axis coextensively with the flexible display throughout a range of rotation between the first portion and the second portion.

20. The device of claim **12**, wherein the hinge assembly creates gaps between the hinge segments and thereby increases a length of a surface of the hinge assembly facing the flexible display as the hinge assembly is rotated from an open orientation to a closed orientation.

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